THE

PRINCIPLES AND PRACTICE

OF

DISINFECTION.

BARTHOLOW.

TO

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IN GRATEFUL ACKNOWLEDGMENT OF NUMEROUS ACTS OF KINDNESS,

AND

IN GENUINE ADMIRATION OF HIS POWERS AS A LECTURER AND TEACHER,

This Monograph

IS INSCRIBED

BY HIS FRIEND AND COLLEAGUE,

THE AUTHOR.

IN the primitive ages Medicine was defined to be the *Art of Healing;* at that time therapeutics was evidently the final aim of that science. Later, when the field of observation had been widened, it was seen that it was often much easier, and always more advantageous, to prevent diseases than to combat them after they were developed. Consequently, the tree of medical science brought forth another branch, called hygiene or prophylaxy, whose special object consists in preserving health, or preventing the development of diseases.

RENOUARD. *History of Medicine.*

Translation of Prof. Comegys.

PREFACE.

THIS monograph contains the substance of three papers read before the Cincinnati Academy of Medicine during the month of April of the present year. New matter has been added, and the whole has been recast for publication in the present form.

In justice to myself I should say that my labor has not been that of a mere compiler. I have been at some pains to ascertain, by experiment on animals, the toxic effects of the gases developed by the process of putrefaction; I have determined by actual trial the actions and uses of disinfectants, and have verified the experiments and observations of others. I may also claim having had a large field for practical observation in a number of years devoted to hospital practice.

The object of disinfection is to prevent disease.

The subject, therefore, pertains to hygiene, the highest, in a humanitarian sense, of all the departments of medical science. To keep clean, it is sometimes said, is the only rule of hygiene, and that if perfect cleanliness be maintained, disinfectants are unnecessary. This is a narrow view. We must accept the evils which belong to our modern civilization. A perfect sanitary state is hardly attainable in the present organization of society. If it were attainable, there is no reason to believe that morbific matter would cease to exist, or cease to fix upon and corrupt our bodies. If the reader will attentively consider what I have said with regard to the substances upon which disinfectants are intended to act, he will understand that the use of disinfectants is to a considerable extent irrespective of cleanliness. The specific virus of disease has unquestionably a power of growth and multiplication independent of those external conditions to which we give the name, bad hygiene; but it is also true that these conditions favor its growth and increase its diffusion.

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INTRODUCTION.

THE use of disinfectants began at a remote period of antiquity. The vicissitudes in the history of these agents illustrate how mankind, even in matters of science, travel in a circle. The empirical knowledge of the ancients, in not a few instances, has had a new birth in the scientific discoveries of the present era. The revival of the practice of disinfection, and the stimulus which has recently been imparted to the investigation of the agents employed for this purpose, have awakened inquiry into the attainments of the ancients in this department of sanitary science. The result has been that agents, which modern investigations have

shown to be the most effectual, were not unknown in the earliest period to which our knowledge extends. Leaving out of consideration the minor art of preserving food, and the practice of deodorization as implied in the use of perfumes and essences—in which the ancients excelled—we learn that the most powerful colytic, antiseptic, or preservative contributed by modern chemistry to the art of disinfection, was employed by the Egyptians, although not in the form in which we are accustomed to use it. I refer to the coal-tar compounds, which in several forms were used by the embalmers. According to Herodotus,* who minutely describes the process, after the viscera were removed from the body, the cavities were filled with gums and aromatics. The body was then laid in "natrum" seventy days; at the expiration of which period it was removed and wrapped in linen imbued with bitumen or various tar compounds. In the case of poor persons, this expensive method could not be practiced. Instead of filling the cavities with costly aromatics in such cases, the embalmers contented themselves with injections of cedar tar,

*Rawlinson's Herodotus, Book ii, chap. 86, p. 121. (See foot notes.)

and for the poorest, the process consisted in nothing more than keeping the body for the prescribed period in contact with the natrum. There has been much discussion as to the nature of the substance, natrum. The learned editor of Herodotus, in a foot note, expresses the belief that it was "not niter, but sub-carbonate of soda, which abounds at the natron lakes in the Lybian desert." This opinion is now generally held.

Sulphurous acid is another agent, the use of which has been revived within a very recent period, but which appears to have been frequently employed by the ancients. It was certainly in use in the time of Homer; for we find in the Odyssey,* that Ulysses employed burning sulphur to fumigate a palace whose inmates he had slain. In the *Fasti* of Ovid, there is an allusion to the same agent for the purification of sheep.† Also, in the "Art of Love," the purification of houses is referred to. Pliny‡ speaks in various places of the use of this substance for the same purposes. "Sulphur," he says, "has its place among religious

*Book xxii, line 492.

†Bohn's edition; translated by Riley. The original was not at hand.

‡Hist. Nat., Lib. xvii, cap. 47; also, Lib. xxxv, cap. 51.

ceremonies, being used as a fumigation for purifying houses." In another place he speaks of burning a mixture of sulphur and bitumen for destroying a disease affecting vines (parasitic?)

The various sanitary evils which render the use of disinfectants necessary were not unknown to the ancients. The most accurate information on this subject has come down to us from the Romans. The hygienic improvements introduced into Rome embodied the experience of the preceding civilizations.

Sewers were constructed at Rome at a very early period—the first, according to Livy,* by Tarquinius Priscus; but the great sewer (*cloaca maxima*) was built by Tarquinius Superbus.†

Strabo, the geographer, (v, pp. 235–6,) thus speaks of the sewers of Rome, and the means used to purify them: "The Romans have surpassed the Greeks by attending to what they neglected, such as the making of high-roads and aqueducts, and the constructing of sewers capable of conveying the whole drainage of the city into the Tiber. . .

* Lib. i, cap. 38.

† Lib. i, cap. 57. *Foros in circo faciendos, cloacamque maximam receptaculum omnium purgamentorum urbis, sub terram agendam.*

The sewers, vaulted with hewn blocks of masonry, are sometimes large enough to admit the passage of a hay cart; and so great is the volume of water conveyed by the aqueducts, that whole rivers may be said to flow through the city and be carried off by the sewers." Pliny also describes in his letters and in his natural history (xxxvi, 15, s. 24) the sewers and the manner in which they were flushed with water to cleanse them. In the third satire of Horace, beginning at line 242,* may be found a reference to the openings on the street communicating with the sewers. So careful were the Romans, in the times of the Emperors, to preserve the health of the city, that persons were appointed (*curatores cloacarum*) to keep the sewers in good condition.

The plentiful supply of water permitted the liberal use of it for public baths and fountains. The immense public baths—of which the baths of Diocletian were the largest—were open at so cheap a rate that all classes of citizens could enjoy their benefits. Not only was the water furnished in great abundance, but special arrangements were

* *Qui sanior ac si*
Illud idem in rapidum flumen jaceretve cloacam?

made to purify it. The aqueducts opened into an immense reservoir, with which three smaller reservoirs communicated; one of these being placed at a lower level received the water which had been purified by subsidence, and this supplied the drinking water.

Special attention was also paid to the manner of building the houses. In the early days of Rome, the streets were narrow and crooked, and the houses were built in solid blocks, and to a great hight. The Romans soon learned the sanitary evils of this system, and hence municipal regulations were made, fixing the hight of the houses, the width of the streets, and the distance of the houses from one another. By a law of the XII Tables it was ordained that the houses should be separated by an interval of 2½ feet. Augustus directed that houses should not be built higher than 70, and the hight was subsequently reduced by Trajan to 60 feet. The tyrant Nero occupies an unenviable place in history for burning a large part of Rome. His conduct subsequently, however, leads us to infer that he was governed by hygienic considerations—for in rebuilding the burnt district, he widened the streets, restricted the hight

of the houses, and in various ways improved and adorned the city. He accomplished, within a few months, sanitary improvements of the same character as those which have occupied the Emperor Napoleon, in Paris, for several years. Whatever may have been the vices and crimes of Nero, we can hardly deny his merit as a sanitarian.

We owe to chemistry, a strictly modern science, the numerous agents now employed for disinfection. This statement is not invalidated by the instances which we have quoted of the use of sulphurous acid and the tar compounds by the nations of antiquity; for these agents also have been rediscovered, and their actions and uses defined by recent experimentalists. Of the large number of substances introduced from time to time as disinfectants, some have maintained their popularity and have justified the confident expectations of their authors; but many, proving comparatively useless, have lapsed into oblivion.

In 1750 Sir John Pringle,* having made numerous experiments, recommended various salts,

*His observations are contained in a work entitled "Experiments on Septic and Antiseptic Substances, with remarks relating to their use in the Theory of Medicine." I have not seen the original.

astringents, and gum-resins. The progress of discovery toward the close of this century quickly supplanted these crude observations. The more powerful agents, chlorine, chlorhydric acid gas, and nitrous acid, were discovered and proposed for disinfection. According to Chevallier,* Hallé proposed chlorine in 1785, and Fourcroy, in 1791–3, extended its applications more widely. Chlorhydric acid gas was introduced into use by Guyton de Morveau, in 1773, and nitric acid was employed by Carmichael Smith, at Sheerness, in 1785. The metallic salts have been proposed at various periods—the sulphate of iron so long ago as 1762; but the most of them have been introduced within the present century.

It would be quite interesting to review the popular delusions which have obtained since the middle ages as to the power of various odorous and volatile substances to prevent contagion. Vinegar, camphor, ammonia, musk, essences and perfumes, sulphur, have had amongst all classes, and have now amongst the ignorant, devoted adherents and believers in their prophylactic powers. This cre-

* *Traité des Desinfectants sous le rapport de l' hygiene publique*, etc., Paris, 1862, p. 3, et seq.

dulity formerly extended to the medical profession. "The physician's cane is a very ancient part of his insignia." "The knob in olden times was hollow, and contained a vinaigrette, which the man of science always held to his nose when he approached a sick person, so that its fumes might protect him from the noxious exhalations of his patient."*

Within a comparatively recent period, the practice of disinfection has acquired greatly increased importance. The alarming ravages of the cattle plague and the present epidemic of cholera have awakened renewed interest in the use of agents to destroy these mysterious animal poisons. New agents and more exact methods have been demanded of science. These demands have not been made in vain. Pettenkofer, the distinguished head of the Bavarian Cholera Commission, Crookes, of England, Dewar, of Scotland, and the Metropolitan Board of Health, of New York, have shown us how much may be done to destroy *materies morbi*, and to arrest epidemics by the judicious and vigorous use of disinfectants.

*A Book about Doctors, p. 12.

I.

SUBSTANCES UPON WHICH DISINFECTANTS ARE INTENDED TO ACT.

THE substances to be disinfected, or upon which disinfectants are intended to act, may be divided into two classes:

1. Those developed in the process of putrefactive decomposition of animal and vegetable matter.

2. That peculiar organic matter to which we apply the terms, virus, *materies morbi*, morbific matter, diseased germinal matter, etc.

With respect to the first class, it may be stated *in limine*, that there is no well-marked chemical distinction between the products of the putrefactive decomposition of animal and vegetable matter. It will be sufficiently accurate for my purpose to regard these products as identical.

Organic substances, as is well known, when removed from under the control of that force which

we denominate, vitality or vital force, are exceedingly prone to change—to a form of decomposition to which we apply the terms, putrefaction, putrefactive decomposition, putrefactive fermentation, etc. The decomposition consists in the rearrangement of the constituent atoms, and the production of simpler forms: it is a declension from the complexity of the organic to the simplicity of the inorganic kingdom. It is a fermentation, and the changes are accomplished under the influence of a body called a ferment. Any nitrogenous matter in a state of change—decomposing—will institute the same process in other nitrogenous matter with which it is placed in contact. This action of contact is called *catalysis*, and hence we have a class of diseases known as catalytic or zymotic diseases.

A certain temperature, and the presence of air and moisture, are essential to the changes which occur in putrefaction. By the action of oxygen, the following changes take place in the organic matter: the hydrogen is converted into water; the carbon passes to the state of carbonic acid; the nitrogen combines with the hydrogen to form ammonia; the carbonic acid and ammonia become carbonate of ammonia; hydrogen, also, combines

with sulphur, phosphorus, and carbon, forming sulphuretted hydrogen, phosphuretted hydrogen, and carburetted hydrogen; certain volatile fatty acids are formed by the decomposition of the fatty matters, (butyric, valerianic, etc., acids,) and, lastly, a fetid organic matter of uncertain chemical constitution is produced, in which the chief toxic properties of the products of putrefactive decomposition reside.

It has been demonstrated by Schwann, Mitscherlich, Schroeder, and others, that animal matter may be preserved indefinitely in air which, after being filtered through cotton-wool, is made to pass through tubes heated to redness; but the moment ordinary air is admitted, decomposition begins. This demonstration led to the interesting discovery that our atmosphere is filled with the invisible germs of those minute organisms—mycoderma, mucedines, bacteria, etc. It has been shown by Pasteur that these organisms are necessary to the process of putrefactive fermentation, just as the *mycoderma cerevisiae*, or yeast plant, is necessary to the process of alcoholic fermentation.

These demonstrations possess great practical value in relation to the subject upon which we are

now engaged. If the presence of organized germs is necessary to the putrefactive decomposition, then the most effectual disinfectants will be those of the antiseptic class, most destructive of these germs.

What is the morbific power of the volatile products of putrefaction?

"We now know," says Parkes,* "that unless the specific cause be present, no mere foulness of air will produce a specific disease." This observation was based upon a careful analysis of all the facts. But the products of putrefactive decomposition produce peculiar effects of their own. In large quantities they produce acute poisoning—vomiting, purging, and great prostration of the vital powers; in small quantity, slowly introduced into the organism, they bring about a state of chronic poisoning, manifested by disorders of digestion, diarrhea, dysentery, and anæmia. These are, it will be perceived, toxic effects, and not specific diseases. The first stage of the primary assimilation being so seriously impaired by the action of the poison, a state of debility is induced, which is very favorable to the reception, growth, and

* Manual of Hygiene; second edition. London, 1866.

development of any specific morbific cause, as the *materies morbi* of typhoid fever, dysentery, or cholera, etc.

Without going over in detail the large number of facts which have been accumulated in illustration of this point, it may suffice to state the conclusions based upon an examination of the facts. As predisposing and exciting causes of disease, there can be no doubt of the agency of the volatile products of putrefactive decomposition. That they produce, when present in sufficient quantity, toxic effects, may also be regarded as conclusively established.

It is obvious that the most important substances upon which disinfectants are intended to act, are those organic matters, or organized structures, which, introduced into the body, produce specific diseases, (*materies morbi.*)

To form an intelligent judgment of the action of disinfectants, we must know something of the nature and mode of action of the *materies morbi.* A number of theories, which account more or less satisfactorily for all the phenomena, have been proposed. In addition to theories, some remarkable facts have lately been developed, which throw new

light on this subject. The theory of Liebig has long exercised great influence over medical opinion, and has impeded the progress of knowledge by substituting a plausible explanation for a careful study of the facts themselves. In the zymotic diseases, the morbific matter is supposed to act as a ferment, or catalytic agent, which, when placed in contact with the solids and fluids of the body, induces molecular changes, correspondent to those which take place in the various fermentations.

When the experimental demonstrations of Pasteur and Schroeder were put forth to the world, the theory of Liebig, before so widely accepted, was now generally called in question. By Liebig's view it is necessary to assume that the morbific material—the ferment—is declining in complexity of composition from an organic to an inorganic substance, and is therefore dead. It is altogether incredible that dead organic matter should possess the wonderful powers of growth and multiplication which we know is the property of *materies morbi*, or that it should impress this power upon other organic matter. The power to grow and multiply is a function of living matter. We must therefore conclude that *materies morbi* is *living matter.*

What particular form does this living matter assume? Is it formless, unorganized germinal matter? Is it an organized form, a vesicle, a germ? Since it has been shown that our atmosphere contains countless germs floating in it, which only need a suitable soil to proceed to full development, numerous observers have turned their attention to this field of inquiry. Previously to the publication of Pasteur's discoveries, various writers had indulged in more or less plausible conjectures of the possible agency of organized germs in the causation of disease, amongst whom I may mention Sir Henry Holland* and Prof. J. K. Mitchell†. The latter delivered a course of five lectures on the cryptogamic origin of malarious and epidemic diseases, which for fertility of resources, variety of illustration, and ingenious hypothesis, has not been equaled in this department of medical research. Amongst the more recent laborers in this field of inquiry, I may mention Angus Smith and Tilbury Fox, of England, and Salisbury, of this State. Dr. Salisbury has published some very remarkable ob-

* Medical Notes and Reflections, chap. xxxi, p. 453.

† On the Cryptogamic Origin of Malarious and Epidemic Diseases. Blanchard & Lea, Phila., 1847.

servations upon the fungus, which causes in the human body the phenomena of periodical fever. If there be no mistakes of observation, nor errors of statement, this discovery will place Dr. Salisbury very high in the ranks of medical investigators. There is a degree of fullness and completeness in his experimental proofs, which leave nothing to be desired. He discovered in malarial districts varieties of the *palmellæ*, and he produced intermittent fever in an individual in whose room at night a box of these organisms was exposed. We might accept this experiment as final, if Dr. Salisbury had not also discovered a fungus with which he produced measles. Instances of honest self-deception are so numerous, and errors of observation so common, that we are compelled to receive with distrust the story of extraordinary discoveries in this department of medical research.

Angus Smith,* of England, has anticipated Dr. Salisbury in these investigations. "In a paper upon the production of malaria, he showed that by simply keeping the ordinary soil of our fields in contact with stagnant water, or, in other words,

* Third Report of the Commissioners appointed to inquire into the Origin and Nature of the Cattle-Plague, p. 160.

without changing the water, an enormous development of animalcular life took place." He admits, however, that he does not consider "there is a necessary connection between malaria and the animalcula." There is a close correspondence between Smith's experiments and those previously made by Pasteur. The rich alluvial soil placed in contact with water at a suitable temperature, undergoes fermentation under the influence of germs, which find in the fermenting substances the conditions suitable for their growth.

M. Fremy,* who has elaborately studied the phenomena of fermentation, comes to a conclusion virtually in agreement with the doctrine of spontaneous generation. Reviewing the other theories, he says, "According to the views of the panspermists, the alcoholic ferment is a sort of vegetable, the germs of which exist in the air and in the juice of fruits; these germs, by a process of development, produce others." In his own view, the yeast germ is only an organized corpuscle; this corpuscle forms itself by an association of many immediate principles; this organic association, as he

* *Traité de Chimie,* etc., *par J. Pelouze et E. Fremy, Tome Sixime,* pp. 916–28. Paris, 1865.

styles it, is determined by different influences, but especially by the action of a semi-organized, soluble body, which is formed during the maturation of fruits or the germination of grains; the process to which we give the name germination, or gemmation, is nothing more than the phenomenon of organic association; the germs of alcoholic ferments do not exist in the atmosphere. Some experiments of Prof. Jeffries Wyman, of Cambridge, seem to confirm this view of M. Fremy. He found that organisms will be developed in solutions, notwithstanding the precautions adopted by Schroeder and Pasteur, to free the air of germs. But Dr. Wyman is a believer in the doctrine of spontaneous generation.

Such conflicting opinions upon the subject of fermentation would seem to be conclusive against the zymotic theory of disease. If so common a process as fermentation is not explicable in the present state of science, it would seem to be idle to base a hypothesis upon it to explain the mode of propagation of a class of diseases.

Beale has well objected to the zymotic theory as being not only unreasonable in itself, but as obstructing the progress of knowledge. This patient

investigator has proposed within the past few years a theory of disease based upon an elaborate series of microscopic studies. He has shown that the power of growth and the production of tissue depend upon minute masses of living matter, to which he has given the name "germinal matter." The nucleus of a cell is germinal or living matter, and the so-called cell-wall is the "formed material" upon its surface. He believes that there is no distinction, chemical, physical, or microscopical, so far as at present can be ascertained, between the normal germinal matter employed in building up tissue and the abnormal or diseased germinal matter, which excites the phenomena of disease. In his own language,* "the highest magnifying powers, hitherto placed at our disposal, serve but to convince us that a minute particle of the germinal matter of the most malignant tumor, or the most rapidly-growing pus-corpuscle, resembles in every particular that can be ascertained a minute particle of healthy, living germinal matter from the blood or from any tissue, and it is proved beyond a doubt, by the same means of inquiry, that the living particles of germinal matter in vaccine lymph

* Report to the Cattle-Plague Commissioners.

can not be distinguished from those present in normal lymph or chyle." In another place* he remarks: "Ordinary pus, then, may readily be produced if the nutrition of the germinal matter of a normal tissue be modified and increased. Under certain specific conditions we are not yet acquainted with, pus, with peculiar and specific properties and powers, is formed, and this last exhibits a far greater activity, and is less easily destroyed than the first."

If these views be correct—and there seems to be no reason to doubt their correctness—we must admit that there is no analogy whatever between the process of catalysis or zymosis, and that modification of germinal matter which results in the production of degenerate forms without altering any of its chemical or physical properties, but only changing the direction of its vital endowments.

The practical applications of this theory are very important. The discharges from the lungs, skin, and intestinal canal of patients suffering from zymotic diseases, contain degraded germinal matter. According to Dr. Beale's view, this de-

* Report of the Cattle-Plague Commissioners.

graded germinal matter, falling into a suitable soil, will grow and multiply, but falling into a soil not fitted for its nutrition, it will die.

Some very instructive and curious observations have been made as to the substances conveyed in the atmosphere which we breathe. A pencil of sunbeams passing through the air of a room, brings into view a multitude of fine particles. It is now well known—as has been stated—that the germs of vibrio, bacteria, and monads of the animal kingdom, and spores of fungi, mycoderms, and mucedines of the vegetable kingdom are found in the air. "Eiselt discovered pus cells in the air of an ophthalmic ward, and epithelial cells are found in all ill-ventilated rooms. In the hospital St. Louis, the dust collected in the wards contained 36 per cent. of organic matter."* From the lungs of men and animals is given off a quantity of nitrogenous matter having a fetid smell and poisonous properties. To this matter chiefly is due the animal odor of badly-ventilated rooms occupied by many persons. This nitrogenous matter in certain states of disease will possess the peculiar property of exciting the same disease in other organisms in

*Manual of Hygiene. Op. cit., p. 73.

which it may effect a lodgment, provided a soil suitable to its growth be present.

Our disinfectants, then, it is obvious, in order to be effectual, must be applied to destroy the noxious gases and the volatile products of putrefactive decomposition, but especially to attack and destroy the virus of disease, the *materies morbi.* The destruction of foul odors will avail us little; for these can be considered only as predisposing causes of disease: our disinfectants should strike deeper, and destroy the disease-producing matter itself.

An important question in this connection yet remains for discussion: What is the seat or *habitat* of disease-producing matter? It is necessary to know this if we would apply disinfectants intelligently. In respect to some forms of disease this question is [illegible]ily answered. Thus we know that the mo[illegible]iples of small-pox and syphilis are c[illegible] pus, which, however, does not differ[illegible]l and chemical properties from perf[illegible]ns. But the information which we [illegible]spect to the morbific matter of mos[illegible] epidemic and contagious diseases (zy[illegible] is not so definite.

zymotic diseases. The organic matter derived from the skin, throat, and urine, may contain the specific virus of scarlatina; the skin and lungs may furnish the specific virus of measles; the secretion of the affected parotid gland may be charged with the specific virus of mumps; the mucous membrane of the fauces may exhale the special virus of diphtheria, etc.; but all such opinions are merely conjectural. In the applications of disinfectants in medical practice the possible sources of the virus should not be overlooked—for much depends upon recognizing its *habitat.*

II.

MODE OF ACTION OF DISINFECTANTS.

ETYMOLOGICALLY, the term disinfection means the destruction of infectious matter. As applied in common usage, it includes deodorization and the power to antisept. These properties are different in character and mode of action, and are not necessarily possessed by the same agent. A deodorant may not be a disinfectant, but a disinfectant deodorizes as well as destroys morbific matter. Notwithstanding the objections which may be urged against the term disinfection, it is now so firmly established in the popular, and even the scientific, language of the day, that it would not be advisable to substitute another. We should not, however, fail to recognize the essential differences in the powers and modes of action of the various agents which have been proposed as disinfectants.

If our knowledge of these agents, and of the

substances upon which they are intended to act, were complete, we could classify them as deodorants, antiseptics or colytics, and disinfectants. An almost insuperable difficulty in the way of a correct classification is experienced in the different kinds of action of the same agent. Thus charcoal, which physically restrains noxious gases, also acts as a catalytic agent, procuring chemical changes in the compounds absorbed within its pores. Sulphurous acid deoxidizes and also arrests chemical changes, or, in other words, acts as an antiseptic. Further, the particular mode of action of some disinfectants is not explicable in the present state of our knowledge. For these reasons, any classification must be more or less defective. The least objectionable is that of Dr. Herbert Barker,* who divides disinfectants into three classes:

1. Agents that chemically destroy the noxious compound.

2. Agents that arrest chemical change. (Antiseptics or colytics.)

3. Agents that physically restrain the noxious compound.

In order to a correct appreciation of the actions

* Hastings Prize Essay.

of these several kinds of disinfectants, we must keep in view the two classes of matter to be disinfected. We have in the first class, it will be remembered, the volatile products of putrefactive fermentation, which may or may not contain the special virus of disease; in the second class, the special virus, *materies morbi*, or the disease-producing matter, under what name soever it may be known.

1. *Agents that chemically destroy the noxious compound.* To this class belong heat, ozone, chlorine, bromine, iodine, nitrous acid, sulphurous acid, and the chlorides and sulphates of mineral bases. I have placed heat at the head of the list, because it is the most powerful and, under some circumstances, the most desirable. Heat may be assigned to each of the three classes into which I have divided disinfectants. It acts, 1st, by the chemical disorganization or oxidization of the noxious substances; 2d, as an antiseptic, by thorough desiccation, thus preventing chemical change, and by destroying the germs necessary to putrefactive fermentation; 3d, mechanically, by inducing movements in the atmosphere. It is employed, however, chiefly with a view to its chemical and oxidizing

power. The action of heat has been carefully investigated by various observers, especially by Dr. Henry,* of Manchester, who published in 1831 a series of very accurate and original experiments. Dr. Elisha Harris, of New York, has published a very interesting paper† on "the utility and application of heat as a disinfectant," in which, in addition to much valuable original matter, he has collected facts from a variety of sources.

The problem which Dr. Henry attempted to solve was this: "Whether any effectual method could be devised of guarding against the introduction of the plague into the country by means of Egyptian cotton, without incurring the serious commercial sacrifices, which then attended the enforcement of the quarantine laws on large cargoes of that article."

Dr. Henry first ascertained that delicate fabrics of cotton, silk, and wool did not suffer any injury at 180° F. He states in a subsequent communica-

* Experiments on the disinfecting powers of increased temperatures, with a view to the suggestion of a substitute for quarantine. A letter addressed to the editor of the Philosophical Magazine.

† Extracted from the published Proceedings of the Fourth National Sanitary and Quarantine Convention.

tion that he found the temperature of these fabrics might be raised to nearly 300° F. without injury to their texture. He next endeavored to ascertain whether the infections and contagions may be destroyed by a temperature below that necessary to injure the texture of the various fabrics, in the interstices of which the morbific matter might find a lodgment. He established that "vaccine lymph is rendered totally inert by exposure to a temperature of 140° F." Experimenting further, he demonstrated satisfactorily that, "by exposure to a temperature not below 200° F. during at least one hour, the contagious matter of scarlatina is either dissipated or destroyed." Dr. Harris gives various facts which he observed in the quarantine hospitals at New York, showing that a temperature of 212° F. destroys the *materies morbi* of yellow fever. One of the most satisfactory demonstrations of the power of heat as a disinfectant, is that related by Dr. Von Busch, of the Berlin Lying-in Hospital. Seeing the utter inutility—says Dr. Harris, to whom I am indebted for the account—of all the efforts that had been made to eradicate a fatal epidemic of puerperal fever, Dr. Von Busch determined upon heating all the wards by common

stoves to a temperature of 150° to 167° F. The result was triumphant. The pestilential infection was completely destroyed. Dr. Harris, Dr. A. N. Bell, of Brooklyn, and others, have given various facts of the same character.

If we admit that *materies morbi* may consist of cryptogamic or infusorial organisms, or of the germs of these organisms, it is necessary to know at what temperature they may be destroyed. Berkeley states in his outlines of British Fungology, p. 32, and in his introduction to Cryptogamic Botany, p. 68, that the spores of certain fungi bear a moist heat equal to that of boiling water without losing their power of germination. As a general rule, it may be stated that these organisms are not destroyed by a less temperature than that sufficient to effect their complete chemical disorganization. We have already seen that Pasteur has demonstrated that these organisms will not devèlop in solutions raised to the boiling point, and hermetically sealed.

The use of heat to induce atmospheric currents is a method of artificial ventilation. Motion of the air favors diffusion, and, also, oxidation of noxious gases and organic matters. But this subject is

foreign to my present purpose, and I merely allude to it in passing.

Ozone plays a very important part in the economy of nature as a disinfectant. Chemists differ in their views of the nature of this mysterious principle, but the most distinguished experts regard it is as an allotropic modification of common oxygen. Various names have been applied to it: ozone, allotropic oxygen, condensed oxygen, active oxygen, peroxide of hydrogen, etc., and various theories of its chemical composition, nature and sources have been proposed, but the central facts, so far as we are at present concerned, are, that ozone is an active oxidizer, that it exists normally in a pure atmosphere, and that it is not found in the air of cities and other places where the volatile products of putrefactive fermentation are abundant. A knowledge of these facts has led to the plausible conjecture that the office in nature of this agent is the destruction—by oxidation—of noxious matters. A great variety of experimental facts which I need not occupy space in detailing prove conclusively that it possesses this power. It breaks up the odorous gases—the compounds of hydrogen—which are given forth from decomposing animal

and vegetable matter, and destroys by oxidation the vague and ill-defined substances to which we give the name, organic matter. As it is consumed in accomplishing these results, we have in this fact an explanation of the disappearance of it from the air of cities. But the chief cause of its disappearance is to be found in the fact that immense quantities of sulphurous acid are given forth to the air in every large city consuming coal; the ozone acts upon sulphurous acid, which passes to the state of sulphuric acid. The absence of ozone may serve to explain the occurrence of the zymotic diseases amongst densely-crowded populations, but it must be admitted that our knowledge is not yet in a state to warrant such a conclusion. There is no evidence that ozone attacks the special virus of disease; its force seems to be expended in destroying noxious odors: it must, therefore, be regarded as a deodorant, rather than as a true disinfectant.

Ozone may be applied to the disinfection of liquids and solids as well as of air. There is a class of oxidizing agents, to which Schönbein, the discoverer of ozone, gave the name *ozonides*. Those employed as disinfectants are the peroxide of hydrogen and the permanganates. These agents part

readily with oxygen combined as ozone. They are applicable, chiefly to the disinfection of water, fluids, and discharges from the body, in cases of disease. They attack and destroy organic matter, upon the presence of which the unhealthfulness of certain potable waters is chiefly due. The peroxide of hydrogen contains one atom more of oxygen than water; hence, when added to water for the purpose of purifying it, this atom of oxygen attacks the organic matter, and water only remains. Theoretically, its action is very perfect, and practically it is found to be useful; but peroxide of hydrogen is an expensive article which necessarily limits its use. "He who cheapens it," says Angus Smith, "will do good to society." The permanganates contain oxygen as ozone, to which their properties are due. They are neat and elegant deodorants, but that they have the power to destroy morbific germs can hardly be admitted. When added to decomposing organic matter, they destroy the odors arising from it, but do not arrest the process of putrefaction. Their effect is, therefore, transitory, palliative, and not fundamental. This conclusion—the result of my own experimental investigations—is supported by the experiments of

Barker, Angus Smith, Crookes, and others, which I need not narrate in detail.

The next agents of this class—chlorine, bromine, iodine—agree as to the manner in which they produce their effects, but differ in the quality and extent of their action. The chemical activity of chlorine is considerably greater than the other two; and it displaces them from their combinations. The affinity of chlorine for hydrogen is the basis of its action as a disinfectant. It decomposes those compounds of hydrogen which are, as we have seen, the odorous products of putrefactive decomposition, uniting with hydrogen to form hydrochloric acid, and setting free the element with which it was combined. This chemical reaction is, of course, the source of its deodorant power; but this does not comprehend the whole of its action. Chlorine decomposes the vapor of water, and liberates oxygen, as active oxygen or ozone, to the action of which much of its deodorant property is due. The most important question is—has chlorine any value as a disinfectant? The experiments made on this point seem to be conclusive. Dr. J. P. Loines,* of New York, has shown that chlorine, in quantity

* Medical Record, March 15, 1866.

sufficient to be irrespirable, does not destroy the activity of vaccine virus. Hence we may assume that, in the quantity usually employed, it accomplishes nothing more than deodorization. The experiments of Mr. Crookes* conclusively establish that chlorine attacks first the odorous gases of decomposition; accordingly, if these be constantly renewed, its effects do not extend to the special virus of disease. To accomplish the destruction of morbific germs, it is necessary that the gas be sufficient in amount to continue the action after the volatile products of putrefaction have been destroyed.

Bromine has precisely the same mode of action as chlorine: it decomposes the hydrogen compounds, and frees oxygen in the form of ozone. It has the merit of facility of application, but in no other respect is it superior to chlorine, and has the signal disadvantage of being comparatively expensive. The action of bromine has been invested with additional interest by the fact that it has been shown to destroy the toxic power of curara and the rattlesnake poison. Iodine appears to be not less effectual; at least, a report to the French Academy

* Report to the Cattle-Plague Commissioners, op. cit.

confirmed the previous statement to this effect, by Brainerd and Green, of this country.*

Notwithstanding iodine is much less active in its chemical relations than chlorine and bromine, it has, in some respects, powers as a deodorant superior to either of them. This has been shown conclusively in some experiments by Dr. Herbert Barker. Iodine combines chemically with animal matters without sensibly altering their forms. It has a much stronger affinity for the protein compounds than for starch. These chemical properties confer upon the iodine considerable powers as an antiseptic.†

Nitric acid is worthy of note as the disinfecting agent which succeeded so perfectly in the hands of Dr. Carmichael Smith about the close of the last century. It has great power as an oxidizing agent, to which its disinfectant and deodorant property is due. It is a very noxious and suffocating gas, and is very injurious when inhaled in considerable quantity. It is, therefore, almost inadmissible in the sick chamber. Where a powerful oxidizer is needed, in vacant rooms or houses, it will probably be found a very effective agent; but at

* *Traité des Désinfectants*, op. cit. † Ibid.

present it is seldom employed, having been supplanted by the next agent.

Nitrous acid is also a powerful oxidizing agent, and is therefore deodorant. As it arrests very completely the putrefactive process and is very destructive of living organisms, it must be classed with the antiseptics as well as the deodorants. Its poisonous character is a strong objection to its use under many circumstances: it may be present in sufficient quantity to produce alarming symptoms without occasioning much irritation of the lungs. In this respect it differs from sulphurous acid, which is obvious to the senses before a dangerous quantity can be inhaled.

The history of sulphurous acid has already been considered. Its use at a remote period of antiquity is well established by the references to it, already quoted, in ancient writers. For many centuries its powers were overlooked. It is within a comparatively recent period that its use has been revived, and that it has taken the place as a disinfectant to which its virtues entitled it. From the earliest period sulphurous acid has been used in the wine-making countries bordering on the Mediterranean, to arrest the vinous fermentation. Re-

cently Dr. Polli, of Milan, has proposed to employ it as a remedial agent to arrest the supposed fermentation in zymotic diseases. During the late epidemic of cattle-plague in England Dr. Dewar, of Kircaldy, employed sulphurous acid as a disinfectant with great success, and he proposes to extend its application much more widely. Mr. Crookes, Angus Smith, Herbert Barker, and others have studied its mode of action and uses as a disinfectant.

Sulphurous acid acts as a deoxidizer; that is, it abstracts oxygen, and passes to sulphuric acid. It also parts with its oxygen readily. Beside this oxidizing and deoxidizing power, in virtue of which it acts as a deodorant, it ranks high among the best antiseptics. It prevents change, decomposition, or fermentation, by abstracting oxygen and by destroying those minute living organisms necessary to this process. Dr. Dewar has tested its antiseptic power very thoroughly and in a very practical manner by subjecting meat to its action, which was afterward prepared and eaten by professional friends, whom he had invited for the purpose.

All the chlorides and sulphates of metallic bases

are useful disinfectants, but they are not all equal in power, utility, and cost. The general truth may be expressed as follows: all salts having a metallic base capable of forming an insoluble sulphide may be used as disinfectants. The base enters into combination with sulphuretted hydrogen forming a sulphide, and the acid fixes ammonia. This chemical reaction is the explanation of their deodorant power. But many of them are also antiseptic; this property being due to their combination with the organic matter, and the production of an unchangeable compound.

Some of these salts, owing to their cost, are practically inapplicable to the work of disinfection. Rejecting these, we have remaining for examination, the chlorides of sodium, zinc, iron, and manganese, the nitrate of lead, and the sulphates of copper, zinc, and iron. Every one is familiar with the preservative or antiseptic power of chloride of sodium. The perchloride of iron has been employed with success for disinfection of cess-pools and sewers, but it has the special disadvantage of producing very disagreeable vapors when added to organic matters. The chloride of manganese is amenable to the same objection. The chloride of

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zinc is not only a very excellent deodorizer, but is also powerfully antiseptic, which renders it a useful agent for the preservation of dead bodies intended for dissection. The chief objection to the chloride of zinc is its cost, which is not counterbalanced by any decided superiority over the sulphates of zinc, copper, or iron. A solution of the nitrate of lead, under the name of Ledoyen's liquid, is much used in France for the disinfection of air, as well as of solids and liquids. Beside the difference in cost, it does not possess any special advantages, when compared with the sulphates.

The experiments of Barker seem to prove that the sulphate of zinc is equally as effectual as the chloride, and it is a much cheaper salt. The municipal regulations of Paris enjoin the use of the sulphate of zinc for the disinfection of urinals and sewers, the contents of which are exposed to public view, because the liquids treated with this salt do not acquire a black color. A mixture of the sulphates of zinc and copper constitutes the *anti-mephitic* liquid of M. Larnaudés. This mixture is believed by Chevallier to possess greater powers as a disinfectant than either salt singly. M. Tardieu regards the liquid of M. Larnaudés as inferior to

the liquid of Ledoyen. The sulphate of iron is equally as effectual as the other sulphates, and has the signal merit of cheapness; but, on the other hand, it labors under the disadvantage of imparting to organic liquids a black color. In the polite capital of France this effect has prevented the use of this salt in any situation in which it might be offensive to the public eye.

A general objection to the use of the sulphates may be urged on the ground that, becoming converted to sulphides, they, after a time, themselves give forth sulphuretted hydrogen; but to correct this, it is only necessary to add an additional quantity.

The most important substances employed as disinfectants are those of the second class—the antiseptics or colytics. The term *colytic*, from κωλυω, "I restrain," was introduced by Angus Smith, "to express that quality, whatever it may be, by which the evident inclination to move is arrested, and is in distinction to that used by Berzelius—*catalytic*, which is the inclination to break up." The colytics prevent action of all kinds. Whilst the oxidizing disinfectants expend their energies in destroying the odorous gases arising from decomposing matter,

the antiseptics put the matter in a condition in which no change can take place, and consequently no noxious gases can be given off. They not only restrain the organic substance, or prevent its breaking up, but they destroy the germs upon whose presence and development the process of putrefaction appears to depend.

To comprehend the mode in which the antiseptics affect morbific matter, we must have correct views of the nature of *materies morbi.* That it is not dead matter seems to be conclusively established. It is certainly living matter, but what form does it assume? Is it a shapeless mass of living or germinal matter? Is it a germ, a cell, or a cryptogamic or infusorial organism? It is upon this living matter, whatever form it may assume, that antiseptics especially act. They arrest action, development, or those phenomena to which we apply the term—life. It follows from this statement that the true disinfectants, if there be any, must be found in the class of antiseptics.

Two important agents of this class have already been alluded to — nitrous and sulphurous acids. Recent observations have shown that sulphurous acid is possessed of remarkable powers as an anti-

septic. I allude to Dr. Dewar's experiments with it, in arresting the cattle-plague, that eminently contagious disease. The coal-tar acids, carbolic and cresylic acids, are very effectual agents of this class. It is a very common error to suppose that these acids are deodorant, and that they destroy the noisome gases of putrefaction; they prevent decomposition, and thus prevent the formation of these gases, but they do not affect them when formed. A variety of experiments by Mr. Crookes show conclusively, that carbolic acid does not act by preventing oxidization, nor by its affinity for albumen, nor by destroying the power of a catalytic agent or chemical ferment.

"The powerful action which carbolic acid exerts on the phenomena of life is the most remarkable property which it possesses. It may be looked upon as the test proper for distinguishing vital from purely physical phenomena."*

The preservative property of the coal-tar acids has long been known. The pitch which the Egyptians used for embalming contained it. The vapor of burning tar, which is so firmly fixed in the popular esteem as a disinfectant, owes whatever

* Report to the Cattle-Plague Commissioners. Op. cit.

efficacy it possesses to the small quantity of carbolic and cresylic acids present in it. Wood smoke, which is employed as a preservative of meat, derives its power from the same source. Dr. Squibb, of Brooklyn, proposes to utilize the latter fact for the disinfection of tenement-houses. He proposes to build a wood fire in the cellar, and smoke the houses as a pork-packer smokes hams.

Carbolic and cresylic—so-called acids—are assigned by the best chemists to the class of alcohols. All of the following alcohols possess disinfectant power: methylic or wood spirit, ethylic or spirit of wine, amylic or fusel oil, phenic or carbolic acid, cresylic or cresylic acid. Creosote prepared from coal-tar is a mixture of carbolic and cresylic acids, and it was at one time supposed that creosote from wood-tar had a similar composition until 1858, when it was shown that wood creosote was a different substance. Pure carbolic acid is a white crystalline solid, which melts at 75° F., but the presence of a small quantity of water or oily impurity renders it liquid. Cresylic acid is liquid. The carbolic acid of commerce, which is usually in a liquid form, is a mixture of carbolic and cresylic acids, but as they are equal

in disinfectant power, the admixture is not objectionable. Commercial carbolic acid is soluble in from 20 to 70 parts of water.*

The agents of the third class are those which physically restrain the noxious gases, or, in the language of Dr. Harris, act as absorbents of moisture and foul effluvia. The substances chiefly employed for this purpose are fresh earth, ashes, lime, and charcoal. The particular action which they exert is that of adhesion. Being in a finely-divided state, they present an enormous extent of surface to which gases adhere. Freshly-burned charcoal possesses this power in the greatest perfection. After a time the charcoal becomes saturated, so to speak, and no more gases will adhere to it, and the same result is observed in the case of the other absorbents. Quick-lime is an absorbent, and, in addition, destroys by its causticity germs and *materies morbi.* These, as is well known, develop most abundantly in moist situations, and are carried up adherent to particles of moisture, by the ascensional force of vapor. A mixture of lime and charcoal, under the name of "calx powder," has been extravagantly praised by

*I am indebted to Mr. Crookes's Report for these particulars.

Squibb, of Brooklyn, who was undoubtedly influenced by the theoretical considerations just mentioned. Dr. Herbert Barker, in the course of his experimental investigations, ascertained that charcoal possessed but indifferent powers as a deodorant, and that of all the agents of this class wood ashes was the most effectual.

Besides absorbing foul gases, the physical agents of deodorization—the finely-divided absorbent powders—act as catalytic agents, and procure the combination of the gases absorbed with the oxygen of the air. Dr. Letheby found that charcoal which had been used to disinfect sewer air contained notable quantities of nitrates. It is obvious that the source of the nitrates in this case was the ammonia and other nitrogenous products of putrefactive decomposition.

III.

APPLICATIONS OF DISINFECTANTS.

THE selection of a disinfectant is governed by the particular circumstances of each case. No single disinfectant is capable of fulfilling every indication. The agent which may be most effectual in destroying gaseous poisons, or aerial morbific matters, may be entirely inapplicable to the disinfection of solids and liquids. As a general rule, if we wish simply to deodorize air, we employ an oxidizing disinfectant in the gaseous form. If we wish to destroy morbific germs, we must select an agent capable of attacking them. If it is our object to arrest putrefactive fermentation, we make use of a colytic, or of a disinfectant having a mineral base which will form an insoluble compound with the organic matter. This branch of the subject, then, is naturally divisible into—

1. Disinfection of air.
2. Disinfection of solids and liquids.

1. DISINFECTION OF AIR. The forces of nature are, when not interfered with by man, adequate to the work of maintaining our atmosphere in a healthy state. The carbonic acid, continually added to the atmosphere by combustion and by respiration of men and animals, is removed by the respiration of plants, which fix the carbon of the carbonic acid in their structures and set free the oxygen. This reciprocal duty, carried on with fixed regularity, has maintained an unvarying uniformity in the composition of our atmosphere. Vast quantities of gaseous and volatile impurities from the habitations of men and from decomposing animal and vegetable matter, and minute solid particles, enter the atmosphere; the gases combine by diffusion with the whole body of the air; some of the impurities are destroyed by oxidation, and disappear, and others, dissolved in the rain, are carried back to the earth. The action of these agencies is greatly promoted by the constant movements of the particles of air. Becoming stagnant, the air soon lapses into a septic condition, especially if favored by moisture and a high temperature. In the septic state those minute organisms, always present to a limited extent, vastly increase in

numbers; organic matters accumulate because the oxidizing agent has been consumed; the true proportions in the mixture of oxygen and nitrogen become altered; carbonic acid increases and oxygen diminishes, and the air quickly becomes unable to support the existence of breathing animals.

No disinfectant can, it is obvious, take the place of VENTILATION. The air in which men live must be brought into immediate communication with the great storehouse of the atmosphere.

Ozone. This being the agent which appears to perform the work of disinfection in our atmosphere, it will be convenient to study the conditions under which it is applicable, before proceeding to an examination of the other agents of the class.

It may be used with safety and without inconvenience in the sick-room, a merit which is not possessed by many of the most effectual agents. There is the further advantage that the fresh air which enters the sick-room from without may be charged with ozone, so that disinfection and ventilation may be accomplished at the same time. On the other hand, it must not be forgotten that it has the power to excite a catarrhal inflammation of the respiratory passages, if contained in the air

in too great quantity. But this effect appears to be the result of individual idiosyncrasies, and does not occur at all frequently. Dr. B. W. Richardson, of London,* has produced inflammation of the nasal passages and of the trachea and bronchi, and congestion of the lungs, in rabbits compelled to breathe an atmosphere highly charged with ozone. In repeating this experiment, I found that a rabbit placed in a glass cage containing ozonized air, continuously supplied with ozone, there being a limited access of fresh air, began to experience distress in an hour, and the effects noted by Richardson followed. Having used the ozone on a considerable scale in the Mercy Hospital for cholera during the epidemic of 1866, in this city, I am justified in asserting that these effects upon the respiratory organs of man do not occur at all frequently, and that ozone may be used without occasioning the least interference with the comfort of the patient, or, indeed, without producing any sensation whatever. Notwithstanding this harmlessness under ordinary circumstances, it would be improper to use ozone as a disinfectant in cases of catarrh, bronchitis, or pneumonia. It is especially indicated in

* Medical Times and Gazette.

all zymotic diseases, in which the respiratory organs are not involved.

It must be admitted that the power of ozone to destroy morbific germs is not great. Its energies are expended in the destruction of foul odors. It must be considered a deodorant rather than a disinfectant in the specific sense; yet if furnished in sufficient quantity to continue the action after offensive effluvia have been destroyed, it will attack septic matters and morbific germs floating in the air.

There are two methods by which the air of a sick chamber may be charged with ozone: by the oxidation of phosphorus and by moistening powdered permanganate of potassa with sulphuric acid. According to M. Houzeau,* it may also be easily obtained by the action of sulphuric acid on the bioxide of barium. The method first named is the one commonly employed, having the qualities of cheapness and facility of application. Some sticks of freshly-scraped phosphorus are placed in a widemouth jar, and partly covered with distilled water. By the oxidation of the phosphorus, the air in the jar acquires the characteristic properties of ozone. By some this action is regarded as an action of

* *Traité de Chimie*, et cet. Op. cit., *tome premier*, *p.* 192.

contact, or catalysis. Schönbein believed that the contact of phosphorus, as well as light and electricity, determined the transformation of ordinary oxygen into ozone.* Whatever may be the explanation, the practical fact remains—that ozone is developed by this process. Barker† has figured an apparatus for regulating the amount of ozone passing into the apartment, but the simple arrangement just proposed will answer ordinary purposes. The amount of ozone generated may be regulated by the surface of phosphorus exposed to the air—in other words, by the quantity of distilled water. The glass jars—ordinary quinine bottles answer very well—should be so placed that the air entering the chamber may be charged with ozone.

The next point to consider is, How can the quantity of ozone present in the air of the sick chamber be estimated? An ozonometer may be readily prepared for this purpose. The following is the method of procedure:

Take 100 grammes of distilled water,
10 gr. of starch,
1 gr. of iodide of potassium.

* *Traité de Chimie.* Op. cit., *tome premier, p.* 188.

† Hastings' Prize Essay.

The iodide of potassium is dissolved in the distilled water, the starch in powder added, and the mixture heated until the starch begins to thicken. Some unsized paper—filtering paper—is dipped into the solution, and when dried, is cut into strips of suitable size. In the absence of Schönbein's ozonometer prepared as above, the substitute of M. Scoutetten may be adopted. This consists of ordinary sized paper—letter paper—which is moistened with the solution of iodide of potassium. The ozone oxidizes the potassium, and sets free iodine, which, combining with the starch, forms the blue iodide of starch. The depth and extent of coloration of the paper is an indication of the quantity of ozone present in the air. A scale has been constructed from 0 to 10 which represents, arbitrarily, the amount of ozone. Some of these strips of paper—ozonometers—should be placed in different parts of the sick chamber to give information of the state of the air.

Chlorine. Chlorine has been much employed as a disinfectant since Fourcroy in 1793 recommended it for the destruction of foul effluvia, contagious virus, and deleterious miasms. Theoretically its action is very perfect, and practically results

of great importance have followed its use. Notwithstanding this, it has often disappointed the expectations founded upon it. These disappointments have been due to two causes: to an extravagant estimate of its powers, and to inefficiency in the method of its application.

Chlorine is certainly a most efficient deodorant, but to accomplish disinfection a very large amount must be used, for it does not attack *materies morbi* until the gases of putrefaction have been destroyed. It is almost inadmissible in the sick-room, owing to its poisonous properties, and to the irritation which it excites in the air passages when inhaled, even in small quantity. For these reasons, ozone is preferable for use in the presence of the sick. Dr. Herbert Barker has proposed a method for obviating this objection. His plan consists in filling small bottles or vials with the gas, and opening them, one at a time, in the chamber at as great a distance from the patient as possible. It is obvious that the execution of this plan will require a special apparatus for preparing the gas and filling the vials. In cities, the bottles filled with chlorine may be procured of the druggist, but under many circumstances it will be impracticable to employ

chlorine in this way. Moreover, the gas in this quantity will accomplish nothing more than deodorization, which may be effected equally well by much milder agents.

Chlorine in combination, in the form of the so-called "chloride of lime," is the most popular of the disinfectants. During times of epidemic visitation the extraordinary increase in the price of this article indicates the extent of the demand and the hold which it has upon the popular favor. This compound is made by treating hydrate of lime by chlorine gas. Two theories are entertained as to the mode in which the chlorine is combined with the lime. One theory holds that there is a direct combination of the lime and chlorine forming a chloride; the other views the compound as a hypochlorite. The latter is, probably, the more correct theory; but there can be no doubt that a portion of the chlorine is held simply by the force of adhesion. The commercial samples vary very much in the quantity of chlorine which they contain.

Exposed to the air the chloride of lime deliquesces and keeps the place to which it is applied wet and noisome. This is an objection to its use.

As a deodorant the chloride of lime is unpleas-

ant, substituting for the odor of noxious gases a by no means agreeable smell of its own. As a disinfectant it is inefficient, because the quantity of chlorine given forth by it is not enough to attack morbific germs successfully. The method of its use during epidemics is often immethodical and unscientific. Thrown into alleys, gutters, cellars, and similar places, as a substitute for cleanliness, it gives out slowly a quantity of chlorine sufficient to be disagreeable without being effectual. It is often placed in the chambers of the sick with a mischievous disregard of their comfort, but with a vague idea that there is some special sanitary virtue in its irritating fumes. Chlorine disengaged in whitewashed rooms combines with the lime to form deliquescent chloride, which keeps the walls permanently damp. Notwithstanding this, it is a most common practice to whitewash tenement-houses and then fumigate with chlorine.

These objections to chlorine should not, however, prevent the use of it in suitable cases. A number of trials have demonstrated its power. But it must be used in large quantity. For the purpose of disinfection it should only be liberated in unoccupied rooms and houses, which may be

filled and the gas allowed to remain in contact with every crevice for several days. It is impracticable to disinfect the external air, and for the deodorization or disinfection of solids and liquids—sewers, gutters, alleys, cess-pools—it is inferior to several mineral salts employed for this purpose.

If it be considered desirable to use chlorine in the sick-room or hospital ward, the following plan is better than the use of the chloride of lime:

> Take 2 table-spoonsful of common salt,
> 2 tea-spoonsful of red lead,
> ½ wine-glassful of sulphuric acid,
> 1 quart of water.

The lead and salt are to be thoroughly mixed with the water, and the sulphuric acid gradually added. Chlorine is disengaged, but is absorbed by the water, which gives it out slowly. The mixture may be kept in stoppered jars and be opened from time to time, as the necessities of the case may require.

On the large scale chlorine may be obtained from the chloride of lime by the addition of sulphuric acid; but this is not a desirable method, owing to the variable quantity of the gas contained in the commercial samples. It may be obtained

from chlorhydric acid, which contains 97 per cent., by heating the acid with binoxide of manganese. The most economical method is to obtain it from common salt. Four parts of common salt, one part of binoxide of manganese, two parts of sulphuric acid, and two of water are mixed and gently heated. When hydrated sulphuric acid acts upon chloride of sodium, sulphate of soda and chlorhydric acid are produced; but the chlorhydric acid in presence of binoxide of manganese is decomposed, water is formed, and chlorine set free.

Packages containing these several ingredients, in the proper proportions for use, are now put up by the manufacturing chemists.

Bromine. In respect to efficiency bromine ranks next to chlorine. As a constituent of the so-called Von Bibron's antidote, it has demonstrated its power to destroy specific virus. As it is, however, chemically, less energetic than chlorine, it can hardly be considered more effectual. During the late civil war it was very much used as a disinfectant in the hospital wards containing hospital gangrene, but it does not appear that it possessed any advantage over chlorine. Its introduction into use was effected through the persistent efforts of Dr.

Goldsmith, of Louisville, who supposed it to have a specific curative power in gangrene. It is readily applied. The vapor is formed at ordinary temperatures, and combines with the air by diffusion with great rapidity—hence it is only necessary to remove the stopper from the bottle containing it. A solution of bromine in water, dissolved by the aid of bromide of potassium, is a convenient mode of using it. Cloths dipped in the solution may be hung up in the sick-room, or saucers containing it may be exposed to the air. Applied in this way it is an excellent deodorant, and may be used without discomfort to the sick; but it is expensive—an objection not counterbalanced by any special advantages. In private practice it may be used with satisfaction.

Iodine. The applications of iodine have been studied by Duroy,* Richardson,† Herbert Barker,‡ and others. Duroy ascertained that it was decidedly antiseptic. His experiments were confined to its use in the solid state upon solids. Richardson proposed its use in small-pox, and it seems, certainly, to be not without influence over the *materies*

* Chevallier. *Traité des desinfectants*, pp. 19–23.

† British Medical Journal, 1863.

‡ Hastings' Prize Essay. Op. cit.

morbi of this exanthem, but additional facts are necessary. Richardson has proposed an ingenious method of charging the air of a sick chamber with iodine. His plan consists in "saturating a solution of peroxide of hydrogen with iodine, and adding 2½ per cent. of sea-salt; by 'atomising' or 'pulverising' the fluid by the little instrument used for the purpose, the air can be charged with iodine and sea-salt spray very readily."* Barker has more particularly examined its action in the vaporous condition. "Iodine in vapor," says Barker, "used in the same quantity as chlorine is equally effective with chlorine in removing offensive odor, when the vapor is freely distributed. The difficulty in using iodine lies in securing its free diffusion. The vapor is deposited unequally in various parts of the chamber: hence the iodine does not remain so universally in action on the offensive substance that is suspended in the air as organic particles, or diffused through the air as gas." To obtain the vapor some crystals of iodine are placed upon a hot plate. For producing a steady and continuous effect the crystals may be simply exposed to the air on a saucer, when, at the ordinary temperature,

* Parkes' Manual of Practical Hygiene. Op. cit.

they will gradually evaporate; or some strips of bibulous paper may be moistened with the tincture and suspended in the apartment. I employed the former method, with satisfactory results, in a hospital ward containing a number of badly-scalded patients, whose suppurating sores emitted an almost intolerable odor. In addition to the constant slow vaporization of iodine at the temperature of the air, a few crystals were occasionally vaporised by heat.

If it were a question as between ozone and iodine in the disinfection of the sick chamber, we would be governed in our decision by the nature of the malady from which the patient was suffering. In some cases an oxidizing disinfectant would be preferable; in others, the influence of iodine over the progress of the case would be considered advantageous.

Nitric Acid. This disinfectant is famous chiefly in consequence of its fortunate use by Dr. Carmichael Smith, who received from the British Government a reward of £5,000 sterling, and the appointment of physician extraordinary to the king. The success achieved by Dr. Smith in the use of this gas was very remarkable, and attracted universal attention at the time.

During the Winter of 1780 an epidemic of malignant fever appeared amongst the Spanish prisoners confined at Winchester, and pr6ved very fatal. Dr. Smith was deputed to study the epidemic, and to suggest means to arrest its progress. He proposed and carried out a system of fumigation* with nitric acid, which proved eminently successful. Five years afterward, at the request of the Lords Commissioners of the Admiralty, he practiced his method of fumigation on the hospital ship, "Union," at Sheerness. The result is thus stated by Chevallier: "The fumigations were continued, and the effects which they produced in purifying the air were remarked by the attendants who no longer experienced a dread in approaching the beds of the sick. Their fears having disappeared, they attended much better to the wants of the patients; hope began to enliven their countenances, which before expressed nothing but terror lest they should be the first victims of contagion." None of the attendants, with one exception, were attacked by the fever after the fumigations were commenced, and this exception was due to a

*His method consisted in heating a mixture of niter and sulphuric acid.

special imprudence. A great amelioration in the severity of the disease took place, and many more recovered. Similar success attended the same measures at Winchester. It is not surprising that Dr. Smith was looked upon as a public benefactor, and munificently rewarded.

Notwithstanding the signal success which attended Dr. Smith's use of nitric acid, it has fallen into disuse, and is now rarely employed for the purpose of disinfection.

Nitrous Acid. This is equally as effectual as the preceding gas, and has almost entirely superseded it. As remarked by Parkes, "The efficient action of nitrous acid is very great on organic matter—it removes the smell of the dead-house sooner than any other gas." This result accords entirely with my own observation.

The gas is readily generated by placing some strips of copper foil in nitric acid. The quantity of gas developed may be regulated by diluting the acid with water. In large quantity the gas is highly poisonous; in very small quantity it may be inhaled without danger; but any considerable amount will produce great irritation of the respiratory passages. Hence, it is hardly admissible in

the sick-room, unless with the precautions proposed in the case of chlorine.

Sulphurous Acid. This gas is probably more effectual, is certainly more generally useful, and is less irritating than chlorine, nitrous acid, and nitric acid. It has the merit of cheapness and ease of application: to produce it the simple combustion of sulphur is alone necessary. When disengaged in a whitewashed room it combines with the lime to form the dry sulphite of lime, which has the same mode of action as the gas, but is, of course, much less powerful. Sulphurous acid, like chlorine, can not be effectually used in the presence of the sick. Dr. Dewar, of Scotland, has, however, shown us that sulphurous acid can be borne to a much greater extent than has been heretofore deemed possible. His experiments in disinfection have led him to propose new uses for this gas in medical practice. In his papers on "sulphurous medication,"* he gives numerous cases showing the curative power of the gas in certain affections of the throat and air-passages and even in phthisis. In diseases affecting these organs it might be supposed *a priori* that the inhalation of sulphurous

* Medical Times and Gazette, May, 1867.

acid, even much diluted with air, would produce suffocative breathing; but there appears to be a great degree of tolerance in these cases.

Dr. Dewar used sulphurous acid very successfully in arresting the spread of the cattle-plague, an eminently contagious disease. Mr. Crookes, who also employed it largely in England in conjunction with carbolic and cresylic acids, confirms the favorable reports previously made by Dewar. This marked success should encourage trials with it in epidemic and contagious diseases amongst men.

Various liquids and solids, properly applicable to the disinfection of solid and liquid substances, are sometimes employed as aerial disinfectants; but they are not so effective as the gases and volatile solids (iodine.) Solution of permanganate of potassa, Labarraque's solution of hypochlorite of soda, Ledoyen's liquid, solutions of various metallic salts, absorbent powders, lime, charcoal, etc., have all been more or less used to deodorize air. It is obvious that their action must be limited to that part of the air which comes immediately in contact with them. Liquids and solids, giving forth a gas, will act efficiently, according to the degree of chemical activity of the gas.

To avoid repetition, the uses of these agents in the disinfection of air will be mentioned in connection with their applications in the case of liquid and solid substances.

Comparative value of the foregoing substances in the disinfection of air. There can be no doubt that for deodorization of the sick-room ozone is the best agent, unless an idiosyncrasy prevent its use. Iodine stands next in convenience and efficiency, and may be preferable in respect to therapeutical indications.

If more decided disinfection is required than can be accomplished by ozone and iodine, sulphurous acid should be used, cautiously.

If an unoccupied room or house is to be disinfected, we have a choice of three agents nearly equal in point of power—sulphurous acid, nitrous acid, and chlorine. I have named these in the order of their relative cheapness and efficiency. No comparative trials, on an extended scale, have been made with nitrous acid and the others. Some very satisfactory trials, on a large scale, have been made with sulphurous acid and chlorine by the Metropolitan Board of Health,* but no decision

* Report of Metropolitan Board of Health, New York, 1867.

appears to have been reached as to their comparative efficiency.

In the words of Dr. E. B. Dalton, sanitary superintendent, "Sometimes chlorine was the agent, and at others sulphurous acid. They have proven equally satisfactory, though in far the largest number the latter was used. In the great majority of instances, fumigation has been followed by immunity from the disease. In a few, however, cases have occurred subsequently to the process, but they have seemed the result of renewed exciting causes." Dr. Dalton narrates a striking instance: "The first house treated in this manner was an emigrant hotel, in the lower part of State-street. Three cases of cholera occurred in this house within a period of thirty-six hours, and a large number of the boarders were attacked about the same time with severe diarrhea. The proprietors were notified that all guests must leave and the hotel be closed. This was promptly done. The house was then thoroughly fumigated with chlorine, and kept so for twenty-four hours, when it was opened and aired. It was then cleansed throughout, and the walls freshly whitewashed. At the end of ten days the hotel was reopened, and very soon crowded with

lodgers. No case of cholera, or other disease of any moment, has occurred there since."

2. Disinfection of Solids and Liquids. The most convenient method of presenting all the facts in this division of the subject will be to show the applications of disinfectants to those fluid and solid substances which require their action, instead of giving the facts under the head of individual agents of disinfection.

Of water. The disinfection of water is a practical subject of great importance. The influence of water, rich in organic matter, upon the public health, is now perfectly well established. If the organic matter is derived from the sewage of cities it may be mixed with specific products. In respect to many cities in this country, especially of the great interior valley, most of the potable waters available for supply contain sufficient organic matter to render their use more or less objectionable. The saline impurities—selenitic and calcareous—are by no means so important as respects the causation of disease. By the term "organic matter," is meant nitrogenous substances of animal and vegetable origin. To deprive the water of this matter is much more important than to free it from

the merely repulsive, visible impurities. Cisterns, containing the usual filtering apparatus, are very much used in many cities. The owners of them congratulate themselves upon the possession of water freed from the foreign matter found in ordinary river water. But the cistern itself may become contaminated, either by direct communication with sewers, drains, and cess-pools, or more indirectly by diffusion—osmosis—through the wall of the cistern, which, in the city, is not unfrequently placed in very close juxtaposition with the privy-vault.

Without entering into the general question of pure water in all its hygienic relations, which would be foreign to my purpose, I propose to consider the means of freeing ordinary potable water from disease-producing matters, and especially from specific products. The disinfectant most relied on for this purpose is charcoal, or a mixture of sand and charcoal as they are arranged in ordinary filters. Freshly-burned charcoal has, undoubtedly, the power to remove all visible impurities, and, also, the organic matter. It is that particular property to which physicists have applied the term, *adhesion;* in other words, the foreign

matters adhere to the charcoal, and pure water passes through. Certain chemical changes, also, take place as I have already explained. If oxygen have access to the charcoal, the organic matters are oxidized; if not, these matters simply accumulate in the interstices of the charcoal, which become clogged up, and the power of adhesion is lost. Charcoal, then, after a time, loses its power of disinfection. Some important experiments have recently* been made by Mr. Byrne which throw light on this point. In a paper read before the Institution of Civil Engineers, he has shown that charcoal after a time begins to give back to the water the organic matter at first separated. It follows from these facts that, to use charcoal successfully in the disinfection of water, it must be frequently renewed, and that the occasional access of air is necessary to promote the chemical changes. It is obvious that filters, as commonly used, do not accomplish perfectly the disinfection of water.

In London since the enormous prevalence of cholera in the districts supplied by the works of the East London Company, a great deal of attention has been directed to the methods of purifying

*London Lancet, June 5, 1867.

the water furnished by this company, which was ascertained to be polluted by the sewage of East London. In addition to the company's filtering beds, which are extensive and apparently thorough in their action, it was proposed to add sufficient permanganate of potassa to oxidize the organic matter. This salt may be more or less successfully used on a small scale, but the plan is impracticable in respect to the supply of a city. A quantity of a solution of permanganate of potassa sufficient to impart a delicate pink, will act upon the contained organic matter, but the water is made to taste of the potassa. Recent investigations* by Prof. Frankland, of the Royal Institution, have led him to the conclusion that the permanganates do not attack equally all forms of organic matter, and that they are therefore not entitled to the confidence reposed upon them by Angus Smith and others.

For the destruction of organic matter in water without impairing the potable qualities of that fluid, no agent is theoretically more perfect than peroxide of hydrogen, which, being added to water containing organic matter, parts with one atom of

*Chemical News, April, 1867.

oxygen, and is reduced to simple water. Unfortunately this liquid is expensive, and can not be procured in quantity.

It follows that the most available and successful disinfectant of potable waters containing organic matter, and especially specific products, is heat. Previous to filtration, potable water should be heated to the boiling point. But boiled water is flat and insipid, because deprived of the oxygen and carbonic acid dissolved in it, and which impart to fresh drinking water its lively taste. Boiled water may be aerated by pouring it through a sieve, kitchen colander, or coarse cotton cloth, and permitting it to fall in a shower a few feet.

Of the discharges of the sick. Morbific matter may be contained in the intestinal and other evacuations of the sick. This fact is tolerably well established with respect to various diseases—typhus, typhoid, the eruptive fevers, dysentery, cholera, etc. Sewage and cess-pool matters, as I have already explained, communicate specific diseases when specific products are mixed with them. The gases developed in the putrefaction of these matters have undoubted toxic power; but the difference between the action of a virus and a poison

is a radical one, as I have been at some pains to show. It is, therefore, a question of great practical importance, How shall we best disinfect the discharges of the sick? There are a variety of agents from which we may choose: solution of permanganate of potassa, chloride of lime, nitrate of lead, chloride of zinc, sulphates of zinc, copper, and iron, and carbolic or cresylic acids. The permanganate acts promptly, but the effect, being expended in the destruction of foul odors, is soon lost. The disinfectants having a mineral base are so nearly equally effective, that the chief consideration in deciding between them is the relative cost. The sulphate of iron is, of course, the cheapest salt; but it is objectionable in that it colors organic matters a disagreeable black. The chloride of zinc is probably the most effectual, but it is also the most expensive salt. The sulphate of zinc is nearly as effective and much cheaper than the chloride, and is, on the whole, to be preferred. It is very soluble, 100 parts of water dissolving 115 parts. A small quantity of sulphate of copper added to the solution increases its disinfectant power. A few spoonsful of the saturated solution should be added to the vessel containing the discharges.

M'Dougall's disinfectant powder, which consists of a mixture of carbolic acid and sulphite of lime, may be used for the same purpose. If the discharges are odorless, a solution of carbolic acid will effectually destroy any morbific matter which they may contain, and will also prevent the development of the putrefactive fermentation. For the disinfection of cholera stools and vomited matters, a solution of carbolic acid is the best agent.

For the disinfection of typhoid fever stools, strong solutions of the chloride and sulphate of zinc or of the mixed sulphates of zinc and copper are the best agents. Next, tincture of iodine, chloride of lime, and solution of permanganate of potassa in the order I have just placed them.

To remove the odor from the sick-room of a recently-evacuated discharge, a few crystals of iodine may be evaporated from a heated plate, or a small quantity of flour of sulphur be burned on some coals upon a shovel, or a few cubic inches of nitrous acid gas be developed from a single strip of copper-foil placed in a half-wine-glass of nitric acid.

To destroy the odor of a water-closet, the most convenient agent is tincture of iodine, exposed to the air on some strips of cloth.

Of cess-pools. For the disinfection of the contents of water-closets and privy-vaults, there are a number of agents from which we may make a selection—we may employ agents of each of the three classes into which I divided disinfectants. The chemical disinfectants having a mineral base and the antiseptics, are most proper. For a prompt effect it is best to use a chloride of zinc, iron, or manganese, nitrate of lead, or a sulphate of zinc, copper, or iron; but to maintain a steady and continuous effect, a colytic or antiseptic should be afterwards added. Consideration of cost will, however, narrow our choice. Other things being equal, the cheapest material is to be used, for the quantity required is necessarily large. The sulphate of iron combines the requisites of cheapness and efficiency. It has been pretty accurately determined that 5 pounds of the iron salt will disinfect 100 gallons of fæcal matters. As the presence of a small quantity of sulphate of copper increases the disinfectant property of the sulphate of iron, one ounce of the former should be added to every 4 pounds of the latter. If the matters are liquid the iron may be added in the solid form, but if they are solid, the iron should be dissolved in

water. Disinfection and deodorization having been accomplished by these means, the next step should consist in the use of antiseptics to prevent further changes. The coal-tar acids and the sulphite of lime are the most available and efficient for this purpose.

Any absorbent matters—the third class of disinfectants—will deodorize a cess-pool, but they merely imprison the gases, and do not destroy them. The best of the physical deodorants is Squibb's "Calx Powders," which consist of lime and powdered charcoal, but the agents of this class should never be used when the chemical disinfectants can be procured. Wood-ashes, and, in the absence of any other material, fresh earth mold will be serviceable.

Of clothing, bedding, etc. An important problem which we have to solve is, The best method of destroying infections contained in bedding, clothing, or other material acting as fomites. Heat to destruction of the material is unquestionably the best, but in many cases the extensive loss of property which this would involve, renders it applicable to a very limited extent. In the previous section it was stated that the boiling temperature, 212° F., proves equal to the destruction of

morbific germs, without impairing the quality of the fabric. Simply boiling the clothes will, then, in many instances, cause the destruction of *materies morbi.* I find in the report of Dr. Harris to the Metropolitan Board of Health some interesting remarks on this point which I quote as expressing the sum of our present knowledge with respect to the use of heat: "Eight years' trial has confirmed our best expectations regarding disinfection of clothing by heat. But, in the course of the correspondence of the Board of Health, the chief medical officer of health in Liverpool, Dr. Trench, also, Dr. Mapother, the learned health officer of Dublin, and a large number of hygeists in Europe have testified to the entire efficacy of heat for this purpose. In the cities of Liverpool and Dublin the sanitary authorities have established portable and permanent heating chambers for the disinfection of bedding, upholstering, and clothing of the poor, and others who have not facilities at home for adequate purification of such articles. . . . . . As regards the soiled and saturated clothing of cholera patients, the experience of the sanitary superintendents and inspectors the past season in the employment of boiling heat for disinfection

seems entirely satisfactory." According to Dr. E. B. Dalton, sanitary superintendent, "all bedding and clothing soiled and used by the patients was boiled in a solution of permanganate of potassa of the strength of one ounce to five gallons of water for two hours, and then removed and reboiled in pure water."

Washing clothes of cholera patients, or bedding stained with cholera dejections, has so frequently been the cause of cholera attacks that it should never be permitted unless steaming or boiling have previously been performed.

There is no difficulty, of course, in the disinfection of clothing by heat, but if we propose to apply heat in the disinfection of houses, we are at once met by numerous obstacles. A special apparatus for heating is the chief difficulty. The movable contents of a house may be readily enough subjected to the proper temperature in compartments arranged for the purpose as is practiced in New York, Liverpool, and Dublin; but to disinfect all parts of a tenement-house by heat will be generally quite impracticable.

Public disinfection. Much may be accomplished by a well-organized health board in destroying

materies morbi, and checking the progress of epidemics by the wise use of disinfectants. The success which attended the efforts of the New York health board, and the measures carried out by Pettenkofer, show that cholera may be successfully combated in this way. The efforts of practical sanitarians should not, however, be restricted to the periodical visitations of cholera. Other zymotic diseases, which may be combated with equal success, are constantly engaged in the work of death. The haunts of fevers, eruptive diseases, dysentery, and diarrhea may be broken up by cleanliness and ventilation, conjoined with the use of disinfectants to destroy the specific disease-producing matter.

Some of the evils of our present social state can hardly be corrected by the means now at our disposal. One of the greatest of these evils is the vast accumulations of sewer and cess-pool matters. If, however, all specific products of disease contained in the evacuations of the sick were at once destroyed by the agents suggested for this purpose, and if all cess-pools were regularly and properly disinfected, a part of this great evil would be obviated. In addition to this, before the contents of cess-pools are removed, they could be rendered

harmless and even odorless by the free use of the more powerful agents employed for deodorization and disinfection.

Modern hygienists propose to abolish the cess-pool and connect the water-closet with the sewer. Such an arrangement will be an improvement, provided a sufficient water-supply be furnished to thoroughly flush the sewers. If the sewers be not thoroughly flushed, the cess-pool matters remain and undergo the putrefactive fermentation.

Since it has been shown that sewer gases exert a deleterious influence upon the public health, numerous expedients have been proposed to remove or destroy them. In Paris, the gutters exposed to public view are disinfected with sulphate of zinc. In London, Dr. Letheby has succeeded in filtering the air passing out of sewers, by trays of charcoal placed in the ventilating shafts. The proof of the success of this expedient is the extraction of nitric acid and nitrates from the charcoal—the nitrogen compounds having been oxidised in the interstices of the charcoal. A few pounds of sulphate of iron, placed in the street openings leading to the sewers, would disinfect their contents and prevent the formation of the deleterious gases.

The use of chloride of lime in alleys, gutters, and moist places—a practice almost universal—is unscientific. The small quantity of chlorine disengaged can not destroy any specific disease-producing matter floating in the atmosphere; this compound is rapidly converted into a soft pasty mass, the chloride of calcium, which has no disinfectant power, and maintains a constant moisture. Now, it is well known, that morbific germs flourish best in moist places, and hence the use of chloride of lime will in the end favor the development of them. For the same reason, this compound should not be used in the damp cellars of tenement-houses. For these situations, Squibbs' calx powder, which consists of lime and powdered charcoal, should be preferred.

The following is a suitable plan for the disinfection of "fever nests," "cholera haunts," or by whatever name may be known those crowded, unhealthy habitations in which these diseases always occur. The whole house should be first thoroughly fumigated with nitrous acid; whitewash should then be applied; the application of the whitewash should be followed by fumigations with sulphurous acid; carbolic acid should be freely used on the floors, in

the cellar, and in the closets; damp places in the cellars and yards should be treated with calx powder, and the privy-vaults should be disinfected with any of the agents recommended for that purpose. Before removing decaying organic matter from yards and alleys, it should be treated freely with common (not purified) carbolic acid and sulphite of lime. If decomposition has far advanced, saturated solutions of the zinc, iron, or manganese salts should be applied. As garbage-barrels in large cities are made the recipients of decomposing animal and vegetable matter, before being disturbed they should be disinfected by any of the substances above named. Garbage-carts should be provided with disinfectants, to be freely used when barrels and boxes are emptied into them. If it be desirable not to impair the manurial value of the garbage, the most suitable agents for disinfection will be sulphite of lime and carbolic acid.

In cholera and fever districts specific products become mixed with the gutter water, and with the refuse of yards and alleys. In the process of cleaning, thorough disinfection should be practiced. The contents of gutters should not, as is sometimes proposed, be swept into the streets, but the gutters

should be thoroughly flushed with water, and the openings into the sewers be charged with sulphate of iron, as already indicated.

The researches of Prof. Pettenkofer, the distinguished head of the Bavarian Commission, have shown that cholera germs are propagated with greatest activity in a soil rich in organic matter, porous, and permitting free access of air and water to a limited depth. He thinks that the surface water (*grund wasser*) plays an important *rôle* in the fructification and transferrence of cholera germs. These views seem to be confirmed by the most recent investigations.* In the practice of disinfection in cholera districts, special attention should, therefore, be directed to the destruction of cholera (diarrhea) discharges, which have become mixed with the soil and subsoil. It should not be forgotten that these discharges are alkaline, and that the cholera ferment is also most probably alkaline. Hence, the use of alkaline disinfectants — lime, chloride of lime, etc. — should not be used to disinfect cholera discharges, for they promote the propagation rather than effect the destruction of cholera germs.

* Report of Weimar Conference.

Purchase of disinfectants. During the prevalence of an epidemic a great many patented disinfectants are offered to the public. It may be safely affirmed that these owe whatever virtues they possess to the presence of some of the well-known and most approved disinfectants, whose properties and uses have been discussed in the preceding pages. A citizen of Cincinnati has recently introduced a mixture of coal-tar and sulphur, which he proposes to burn in a stove constructed for the purpose. The preparation and the method of its application are very good, but the idea dates back to the time of Pliny, who, as we have seen, recommended a similar mixture—bitumen and sulphur—for fumigating diseased vines. In England M'Dougall's powder has for some years past been a favorite agent, and this consists of carbolic acid and sulphite of lime—a combination almost identical with the results of combustion in the case of the coal-tar and sulphur. Since it has been shown that carbolic acid possesses extraordinary antiseptic power, various preparations of this substance have been introduced under various names. Thus, the "Ridgewood disinfectant" contains about 8 per cent. of carbolic acid mixed with a silicate. "Carbolate of

lime," so called, is another compound recently introduced. In most of these compounds the quantity of carbolic acid is small, but to make it appear abundant, coal-tar is added, which has a powerful odor, but inferior disinfectant power. Generally a price is fixed upon these patented articles, quite as high as that demanded for the pure articles; the true economy, then, consists in purchasing the disinfectant itself, rather than an adulterated mixture containing it in insufficient quantity.

It has recently been proposed to utilize the "retorted slate," the residue of the oil-bearing shales which remains after distillation of the oil. This will be found to possess considerable disinfectant power, and is of course inexpensive. It may be used as a substitute for the so-called calx powder in the disinfection of moist places, and it is applicable to the disinfection of privy-vaults and other organic matter in the solid state. It is exceedingly well adapted to the manufacture of "*poudrette*," for, whilst it deodorizes ordure, it rather increases than impairs its fertilizing properties.

Various solutions of the metallic salts have been patented, or secret preparations have been made, and offered to the public as possessing some special

advantages. These are generally inferior in strength and certainty to the ordinary commercial samples of the metallic salts. Labarraque's solution of hypochlorite of soda is a neat and convenient agent in medical practice, but it has not powers of disinfection superior to the common chloride of lime. The liquids of Ledoyen, Larnaudès, and Sir William Burnett possess no advantages over simple solutions of the metallic salts of which they are compounded.

APPENDIX.

RECENT PAPERS ON DISINFECTANTS.

A NUMBER of papers of considerable merit have appeared, within a few years, upon the subject of disinfection. The only special treatise, so far as I have been able to ascertain, is that of M. Chevallier. I propose to review briefly the most important of these contributions to the subject of disinfection, and present short abstracts of the more salient opinions of their authors.

TRAITÉ DES DÉSINFECTANTS, *sous le rapport de L'Hygiene Publique, par M. A. Chevallier, Pharmacien—Chimiste, etc. Paris.* 1862. *Pp.* 180.

This volume treats of disinfectants under three heads: gases; solids or liquids; solids. Under each article the author gives an interesting historical account of its introduction into use. He places chlorine at the head of the list of gaseous disinfectants. His extravagant estimate of the value of the chloride of lime may be

inferred from the fact that he devotes seventy-five pages of his work to a consideration of its actions and uses.

Carbon is another agent, for which he has a special predilection, as he devotes thirty-two pages to its employment in disinfection.

ON DEODORIZATION AND DISINFECTION. *By Thomas Herbert Barker, M. D., F. R. S. E. The Hastings' Prize Essay for* 1865.

Dr. Barker has studied the subject of disinfection from the experimental side. "There are two methods," he says, "by which a writer, who has some experience in the use of deodorants and disinfectants, may put forward his knowledge. He may adduce his experience of disinfectants, as derived from his observation of their action in the sick-room; or he may follow an experimental research, and draw conclusions therefrom." He preferred, for reasons which he has given in detail, "to rest mainly on the second, or experimental basis of research; that is to say, he has taken organic matters, and subjecting them to processes of decomposition under various and varying conditions, has endeavored, by the use of deodorizing and disinfecting agents, to find the readiest means of removing or destroying the decomposing products, or of holding the process of decomposition itself in abeyance."

Dr. Barker selected the intestines of the ox as the

most convenient organic substance for the purpose of his experimental inquiry. His first series of experiments were entitled "Observations on the Decomposition and Deodorization of 2 lbs. weight of intestines from an Ox, buried in 2 lbs. of Saw-dust, with the substances described; with Observations on a similar weight of intestines exposed to common air." The disinfectants employed in this way were sulphate of zinc, chloride of zinc, chloride of sodium, lime, charcoal, alum, creosote, tincture of iodine, carbolic acid, vinegar, and saw-dust alone.

As a result of these observations he concluded:

1. Chloride of zinc and sulphate of zinc are the best deodorizers in combination with saw-dust. Practically there is no difference between the two salts.

2. After the preparations of zinc, carbolic acid stands best in the list of deodorizers.

(In this conclusion he is opposed by both Angus Smith and Crookes, who have shown that carbolic acid *prevents putrefaction*, but does not affect its odorous products when formed.)

3. Lime, when combined with saw-dust, can scarcely be considered a deodorizer at all. In it organic matter becomes offensive in four days.

4. Charcoal, contrary to what ought to be expected, is comparatively a feeble deodorizer, even when used quite fresh.

In another series of experiments in which he compared the deodorizing power of charcoal, earth-mold, and wood and coal ashes, he ascertained that charcoal,

"used quite fresh, possesses a very limited deodorizing power," that earth-mold is inferior to charcoal, and that wood-ashes have a "very decided deodorizing property."

In the next series of experiments he attempted to determine the power of deodorization possessed by different agents, in the case of organic matter in a state of decomposition. His method of procedure was the same as in the preceding experiments; that is, the decomposing intestines were buried in sawdust with the disinfectant in the solid form. He concludes from these observations, that, "for the deodorization of putrescent organic matter, as well as for the preservation of fresh matter, chloride and sulphate of zinc are by far the best agents."

Experimenting with disinfectants in the liquid state he used pieces of liver in the first series in the fresh state, and in the second series decomposing. In the first series he ascertained that the following disinfectants were nearly equally good in preventing decomposition: alcohol, Sir W. Burnett's fluid, the saturated solution of sulphurous acid, Beaufoy's liquid, tincture of iodine, solution of sulphate of magnesia, solution of chloride of sodium, solution of sulphate of iron, solution of nitrate of lead, solution of sulphate of copper, solution of sugar, pyroligneous acid, solution of chloride of potassium, solution of alum, and turpentine. On the other hand, solutions of peroxide of hydrogen and of permanganate of potash were not at all effective. In the second series, the same agents

were used with decomposing liver, with the following result: the offensive odor was destroyed in pyroligneous acid, in Sir W. Burnett's fluid, in solution of sulphurous acid, in Beaufoy's liquid, in tincture of iodine, and in turpentine.

Dr. Barker next proposed to test the preservation of animal fluids by various deodorizing substances used in solution. Experimenting with various disinfectants upon defibrinated blood, he ascertained that "the substances which prevent entirely the decomposition of blood for a period of twenty-five days are, pyroligneous acid, carbolic acid, creosote, bromine, and turpentine." Tincture of iodine, solution of nitrate of lead, and Sir W. Burnett's fluid were less effective.

As a result of his experiments on fetid air, we learn that "the most powerful deodorizer, and—if Angus Smith's test be taken as faithful in respect to the destruction of organic matter—the best disinfectant is chlorine. But when the odor of chlorine is lost, its efficacy may be considered as having ceased." "Next to chlorine is thorough ventilation." "After ventilation, nitrous and sulphurous acid stand next in order." "Ozone appears to be less active in so far as the permanganate is concerned, than either chlorine, nitrous acid, or sulphurous acid. It, however, destroys the ódor as effectually as the others, and almost as rapidly as chlorine, which, in action, it closely resembles." "Iodine in vapor, used in the same quantity as chlorine, is equally effective with chlorine in removing the offensive odor when the vapor is freely distributed.

The difficulty in using iodine lies in securing its free diffusion."

Dr. Barker makes a great many very practical and useful observations in respect to disinfection in medical practice. For the disinfection of the discharges of the patient, he decidedly prefers iodine and carbolic acid. "For the ordinary chamber utensil, iodine may be used, either in the solid form or as tincture. Half a drachm of the former, or half an ounce of the latter is sufficient." The considerable cost of iodine is certainly a strong objection to its use under many circumstances.

"Carbolic acid may be used in the same way in quantities of from one to four drachms. . . . I consider it, therefore, less valuable than iodine."

For the deodorization of the dead body waiting for burial Dr. Barker prefers a salt of zinc—usually the sulphate—in combination with saw-dust.

He concludes his very instructive essay with the following summary:

1. For the sick-room, free ventilation when it can be secured, together with an even temperature, is all that can be required.

2. For rapid deodorization and disinfection, chlorine is the most effective agent known.

3. For steady and continuous effect, ozone is the best agent known.

4. In the absence of ozone, iodine, exposed in the solid form to the air, is best.

5. For the deodorization and disinfection of fluid

and semi-fluid substances undergoing decomposition, iodine is best.

6. For the deodorization and disinfection of solid bodies that can not be destroyed, a mixture of powdered chloride of zinc, or powdered sulphate of zinc with sawdust, is best. After this, a mixture of carbolic acid and sawdust ranks next in order, and following on that wood-ashes.

7. For the deodorization and disinfection of infected articles of clothing, etc., exposure to heat at 212° F. is the only true method.

8. For the deodorization and disinfection of substances that may be destroyed, heat to destruction is the true method.

Two of the most valuable and instructive essays which have appeared upon the subject of disinfection are to be found in the

THIRD REPORT *of the Commissioners appointed to inquire into the Origin and Nature of the Cattle-Plague.*

ON DISINFECTION AND DISINFECTANTS. *Report to Her Majesty's Commissioners. By R. Angus Smith, Ph. D., F. R. S., etc.*

ON THE APPLICATION OF DISINFECTANTS *in arresting the Spread of the Cattle-Plague. Report to Her Majesty's Commissioners. By Wm. Crookes, F. R. S.*

The report of Dr. Angus Smith is occupied chiefly with experimental demonstrations. It is remarkably

rich and full of data, and is therefore specially deserving of careful examination. His first experiments were made with a view to ascertain the influence of volatile substances in preventing putrefaction. Here cresylic acid and fusel oil stood first, and carbolic acid and creosote second. In his comparative trial of strong gases he ascertained that chlorine, bromine, iodine, nitrous acid, and sulphurous acid were all effective in preventing decomposition.

He gives an elaborate series of experiments to show the relative efficiency of the different agents for disinfection in water. He sums up his conclusions as follows: "Arsenious acid, corrosive sublimate, sulphate of copper, and chloride of zinc are the most active agents." "The phenylic and cresylic alcohols, which experience has shown to be generally so active in the prevention of putrefaction, are not sufficiently constant when a large quantity of water is present."

From a series of experiments to determine the relative value of different disinfectants, for the removal of bad odors, he arrived at the conclusion that "even the most powerful antiseptics are far from being well fitted for removing putrid smells, when added in a strong state." Chloride of iron acts better than chloride of zinc, but acids and metallic salts send out a strong odor when added to decomposing organic matter. Chloride of lime, he concludes, acts better than any of the salts just named.

The substances best suited to prevent decomposition, when water is present, are the acid metallic salts. He

prefers chloride of zinc and sulphate of copper, but thinks chloride of iron is effective. "Common salt stands very high in this test. . . . It seems to have been forgotten that the substance which preserved sound organic matter would also preserve refuse."

For disinfection, where there is little water, "the tar acids do not seem to have any rivals. Dry sulphites mixed with them are an improvement."

"For disinfection, when putrefaction has advanced and the smell is to be removed," he thinks, "there is perhaps nothing superior or even equal to chloride of lime, unless we except peroxide of hydrogen and permanganate of potassa."

Dr. Smith concludes his paper with some observations on the methods of applying disinfectants in arresting the spread of cattle-plague.

Mr. Crookes's investigations were more particularly directed to the practical application of disinfectants. He has, however, prefaced his trials of disinfectants with some "theoretical considerations as to the propagation of cattle-plague," which possess great interest, and with a chapter "on disinfectants generally," in which he makes a very careful and exact analysis of these agents and the particular conditions to which they are applicable.

For the special purpose of his inquiry Mr. Crookes was limited to the oxidizing disinfectants, chlorine and ozone, and to the antiseptics, sulphurous and tar acids. His preconceived ideas were strongly, he says, in favor of ozone and chlorine, but the irresistible force of the

arguments derived from his experiments caused him to alter his opinion. He shows that the oxidizing disinfectants act upon the odorous gases of decomposition, and do not reach the virus of infection; "they remove the products of decomposition, but they do not take away the power of further putrefaction."

"Oxidizing disinfectants produce their effect by actually destroying infecting substances. Antiseptics act simply by destroying their activity. The former act more energetically upon dead than living organic matter. Antiseptics attack first the opposite end of the scale and destroy vitality; they exert little or no action on the foul-smelling and comparatively harmless gases of decomposition, but they act with intense energy on the inodorous germs of infection which these gases may carry into the atmosphere along with them."

Mr. Crookes proves that sulphurous acid has a great power to destroy the vitality of germs; that it is powerfully antiseptic, and that it has considerable energy as a deodorizer. He gives a number of very interesting experiments to show the mode of action of the tar acids—carbolic and cresylic acids. He proves that these acids do not act by preventing oxidation; that they have scarcely any action on fetid gases; that they do not owe their special action to their coagulating powers on albumen, and that they have no action on purely chemical ferments. "It may be considered as definitely proved that the vapor of carbolic acid in the atmosphere exerts a special selective power on all minute organisms possessing life. . . . . French

experimentalists have repeatedly tested the influence of carbolic acid on vaccine lymph. They have employed lymph both pure and mixed with carbolic acid. The vaccination with pure lymph was followed by the usual results, but in no single instance was any effect produced by the lymph containing carbolic acid." Mr. Crookes's plan of disinfection embraced the use of sulphurous acid for the purpose of purifying the cattle sheds two or three times a week; and the employment of carbolic acid as a permanent means of protecting the animals from extraneous infection.

"Sulphur fumigation and carbolic acid agree very well together, and somewhat assist each other's action."

The remarkable success which attended Mr. Crookes's experiment in arresting the cattle-plague is conclusive as to the accuracy of his views, and the value of the agents employed by him.

REPORT OF COMMITTEE ON DISINFECTANTS. *Transactions of the American Medical Association. Vol. xvii.*

This paper contains a good deal of valuable matter, but it is, also, disfigured by numerous errors, some of them, probably, of proof-reading. There are, however, various singular statements which can hardly be accounted for in this way. Thus, in discussing the action of chloride of lime, the reporters make this extraordinary statement: "It will be noted that in such a preparation as this, we are able not only to avail ourselves of the value of the chlorine which is

set free, but as it holds oxygen loosely, or in a nascent state, as it is called, it is quite ready to emerge from its state of combination," etc. They evidently refer to the decomposition of the vapor of water by chlorine, the formation of chlorhydric acid, and the setting free oxygen in its allotropic state. In some remarks on the mode of action of the chloride of zinc, there occurs another error. "It decomposes sulphuretted hydrogen, forming *sulphate* of zinc."

The committee called the attention of the profession to the "lime and salt mixture," which is prepared "by adding one hundred of salt to three hundred weight of fresh lime"—chloride of lime being a product.

In some observations on *nitrous* acid, the committee refer to Dr. Carmichael Smith's experiments. It is certainly true that Dr. Smith called his method of fumigation *nitrous* fumigation, but in this he was mistaken. By heating niter with sulphuric acid he obtained fumes of *nitric* acid. The committee propose to obtain nitrous acid "by covering a quarter of a pound of shavings of copper with commercial oil of vitriol!" The committee differ from Angus Smith, Crookes, and others in assuming that coal-tar acids are "powerful deodorants." They also believe that the deodorant power of charcoal has not been overrated.

The committee very properly object to the patented disinfectants, and advise the use of the well-known agents whose efficiency has been determined by numerous trials.

DISINFECTION. *By E. R. Squibb, M. D.*

This is an interesting and instructive pamphlet, a reprint of a report made to the New York Academy of Medicine. Dr. Squibb's prejudices are strongly in favor of chlorine and the absorbent powder, which he introduced under the name of "calx powder"—a mixture of lime and charcoal. In this combination he relies upon the power of charcoal as an absorbent of gases and noxious effluvia, and as a catalytic agent, and upon the causticity of lime for the destruction of germs which are carried up by the "ascensional force of vapor." It may be urged against these views that charcoal quickly loses its power, and that lime does not destroy morbific germs. Alkaline substances promote the development of cholera germs.

CIRCULAR NO. 5. *War Department. Surgeon-General's Office. Report on Disinfectants and their use in connection with Cholera.*

This is a very condensed statement of the existing knowledge on the subject of disinfectants. Dr. Craig, the author of this report, regards the use of the sulphate of iron, or some other metallic salt, such as chloride of zinc, as the most important of the disinfectant measures to be adopted during the prevalence of cholera. He strongly enjoins the use of permanganate of potassa for the purification of drinking-water during cholera epidemics. He makes no allusion

to the very conclusive experiments of Professor Frankland, showing that permanganate of potassa does not act equally on all forms of organic matter; but he adheres to the doctrines taught on this subject by Angus Smith. Dr. Craig had previously made the same observations on the purification of potable water by the permanganate solution, in the seventeenth volume of the Transactions of the American Medical Association; but this plan had already become the common property of the profession.

Dr. Craig's principles and practice do not always correspond. Thus, admitting that the cholera virus is an alkaline ferment, he advises the use of lime "wherever there are moderate quantities of organic matter in a moist condition," as a means of disinfection during cholera epidemics.

In addition to the foregoing, the reader who desires to pursue this subject will find articles in *Muspratt's Dictionary of Chemistry;* in the *Proceedings of the Third*, also, in the *Proceedings of the Fourth National Sanitary and Quarantine Convention;* in the *North British Review for June*, 1866; in the *Report of the Metropolitan Board of Health for* 1866; in *Parkes's Manual of Practical Hygiene*, second edition, London, 1866. Dr. Elisha Harris, a distinguished sanitarian of New York, in addition to papers published in the proceedings of the quarantine conventions, has proposed a classification of disinfectants, and made suggestions as to their use, in a Sanitary Commission Document

entitled "Hints on the Control and Prevention of Epidemic and Contagious Diseases."

I am indebted to Dr. Harris for a manuscript copy of the very excellent instructions on the use of disinfectants, issued by the Metropolitan Board of Health to their officers.

Various works on Materia Medica and Therapeutics contain, under the head of individual articles, pretty full details of the history, actions, and uses of the agents employed in disinfection. The elaborate works of Pereira and Stillé deserve especial mention in this connection. In general, however, the fullest information is to be obtained from the more modern works on hygiene, with which department of medical science the practice of disinfection has the closest affinities.

NAME	DATE DUE